Automated intellectual system with the short-duration nature of feedback

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Abstract. The necessity of using in the drilling rigs the automated intellectual system with short-duration nature of feedback providing quick, timely system response for the properties changes to the object of influence and adjusted parameters of the technical systems "Drilling rig – rolling cutter bit - rock" operating in the optimal ratio maintenance was proved. The implementation by the intelligent system of the mentioned problems will allow us to reduce drilling costs and to improve the effectiveness of the specified technical system operating. The advantages of this system over its analogues are pointed out. A technological and schematic diagrams of the investigated system functioning were developed.
[Stupina A.A., Shigina A.A., Shigin A.O., Karaseva M.V., Ezhemanskaja S.N. **Automated intellectual system with the short-duration nature of feedback.** *Life Sci J* 2014;11(8s):302-306] (ISSN:1097-8135). http://www.lifesciencesite.com. 67

Keywords: automated intellectual system, short-duration feedback, technical system, object of influence, object of control, monitoring and control system

Introduction

Control systems play an important role in the automation and control by technological processes in mineral resource industry. Currently the problem of such systems development is very urgent because it is impossible to improve the efficiency of control without the automated control systems (ACS) based on application of information technologies and advanced mathematical control models [1-3].

However modern automated control systems by drilling rigs do not allow us to respond to the changing object properties (of rocks), to adjust the operating modes and to compensate disturbances at the operation of complex technical systems "Drilling rig – rolling cutter bit - rock" (hereinafter called an object of control), that reduces its efficiency. Moreover, in modern control information systems there is no opportunities to make decisions about parameters changing at changing object properties, as well as knowledge databases in the form of a special mathematical models reflecting the progress processes in the system of informational processes that cannot take into account all the diversity and complexity of problems occurring while the ASU operation. Providing with the specified requirements for timeliness and accuracy of the information transferring considered to be the fundamental condition for the quality of control improving by the object and process.

The investigation urgency in the field of intellectual ACS is that in the conditions of increasing requirements to the features of information exchange in the ACS the requirements to the systems quality of data transmission operating are increased quickly [1].

The aim of this paper is to substantiate the necessity to use automated intellectual systems (AIS) with the short-term nature of feedback in the drilling rigs to increase the service life of the expensive drilling tools in about two times, to improve the drilling efficiency and to reduce the cost of the drilling process. The short-duration feedback is realized by the sensors signal and it serves to maintain the parameters of the technical system operating.

The investigated AIS will allow us to trace in proper time the properties changes of the object of influence in the process of the object of control (monitoring) functioning, to determine its forecasting resource, to make adjustments to the operating parameters in a constant mode and to ensure successful solution of the problems with a priori incompleteness and fussiness of the initial data, as well as the characteristics variability and inaccuracy of the investigated object of influence.

Control by structural dynamics of the complex technical system

The perspective direction of the artificial intellect development was based on the works on the fundamentals of control theory by structural dynamics of the complex technical systems [4-8]. This direction offers to use complexes with different models, combined methods and algorithms, as well as the development of intellectual technology of automatic monitoring design and control of complex technical objects in various conditions of the situation changing.

The monitoring and control process analyzes the transition of the system structure from one state to another under the influence of various reasons (environment influences, conflicting systems, etc.).

The authors defined the place of control theory by structural dynamics of complex technical systems as the integration of artificial intelligence with systems analysis, operations research, control theory and systems theory, i.e. it requires interdisciplinary studies [4]. The problem concept of control by structural dynamics of complex technical objects is reduced to the solution of the following main problems:

- analysis of the structural dynamics of the complex technical system;
- evaluation of the system structural state;
- selection of optimal control programs and regulation by the structural dynamics of the system.

The main role in this control belongs to the integral systems of decision making [4, 9-10].

The structure interacted with the environment and in the process of necessary information receiving it forms the target of action and analyzing the impacts on the system (physical and information) is usually applied for the generalized intellectual systems. The defining elements of the control system in this case are the intellectual converter and basic system of control [11].

In case of use in the control system of artificial intelligence as the intellectual converter [11] the expert systems [12-14], situational control [15], control by the structural dynamics of complex technological [4, 16-17] and other intelligent systems and their elements are implemented.

The use of dynamic expert systems containing two blocks: synthesis and target implementation [11] is represented as an example of the smart converter use in the system of control (Fig. 1).

Mathematical model of the intellectual control system contains three parts:

- intellectual converter;
- object of control;
- controllable unit of the system (computational and converting units).

The intellectual converter changes the information about the external environment and the object of control and it transforms the impact signals on the controllable unit of the system [11]. To generate impacts on the object of control system the decision making block is use in this converter [9-10].

The modeling of dynamic processes of the drilling rig functioning is realized with the purpose of parameters of the drilling process optimization [18]. However, as criteria to be optimized, it is proposed to choose the speed of drilling, deepening and bits reliability, power of feeding and rotation mechanisms, the drilling cost of one meter of borehole cavity and so on. The permanent control for the amplitude and frequency parameters of dynamic loads is necessary.

In the mining industry in conditions of uncertainty and incomplete information about the properties of the object of influence at modeling processes it is necessary to use the average data included the drill ability indicator and its change, number and size of areas with changing properties of this object [19-20].

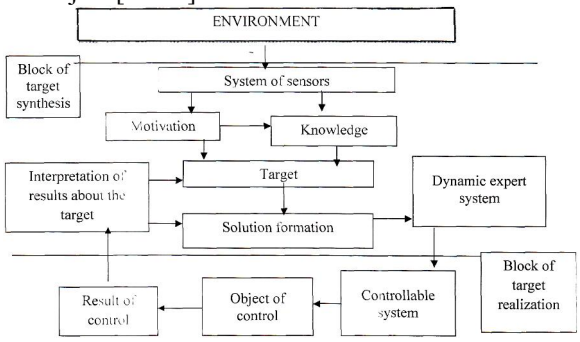

Fig. 1. Structural scheme of the system of the intellectual control with the dynamic expert system

Analogues of the investigated AIS

The analogues of the automated intellectual system is "On-board control system of drilling rigs (OCSD)" (in Russian market), "Intellectual control system of drilling "Smart Drill Monitor" ("ICSD SDM") machine MD5150 of the company "Caterpillar", "Automated control system of drilling rigs" ("ACSD") (in the world market) and others (table 1).

Table 1. Advantages over the analogous of the investigated AIS

Technical and economical characteristics	Names of the AIS analogues			Names of the investigated AIS
	Federal level	World level		
	"OCSD"	"ICSD SDM" machine MD5150 of the company "Caterpillar"	"CCSD"	AIS with the short-duration nature of feedback
Possibilities to the system reaction for short-duration changes of physical and mechanical rock characteristics	No reaction	No reaction	No reaction	Adaptive system reaction without human participation
Time reaction for the steady (systematic) change of physical and mechanical rock characteristics	More than 20 sec.	~0,1 sec.; time of transferring processes–more than 0,1 sec.	~0,1 sec.; time of transferring processes–more than 0,1 sec.	0,01 sec.

The investigated AIS is able to react quickly (hundredths of a second) for the short-duration properties changing of the object of influence unlike its analogous. The advantage of the short duration nature of the feedback of the investigated AIS is that the response time of the system to the steady (systematic) changing the of the object of influence properties without human participation is 0.01 sec. The AIS analogues in the world market presented in

Table 1 has the actuation time of the automatic system of about 0,1 sec., and the duration of the transferring processes of the operating units is more than 0.1 sec. In "On-board control system of drilling rigs (OCSD)" (a federal level) the response time of the operator to the significant and prolong changes is more than 20 sec., that reduces significantly the control process effectiveness.

Control system by AIS

The investigated AIS uses nonlinear feedback (a closed-loop control system), as it is necessary to use in the system complex nonlinear equations that transform an information signal in the computer. Since the mentioned AIS has several local feedbacks, it will be a multi-circuit one.

For the influence control formation in a closed-loop control system, the deviation of the current value of the controlled number of the required value is used.

To improve the accuracy control in the investigated AIS a combination of a control system built on the basis of combination of the control principles by disturbance and deviation is used. To use this type of control, it is necessary to have the opportunities to measure the main disturbance. The deviation will be discovered by the system and abandoned by a control unit

Operating of AIS with the short-duration nature of feedback

The general technological scheme of the developed AIS (an intellectual system of monitoring and control) of the drilling rig is as follows (Figure 2):

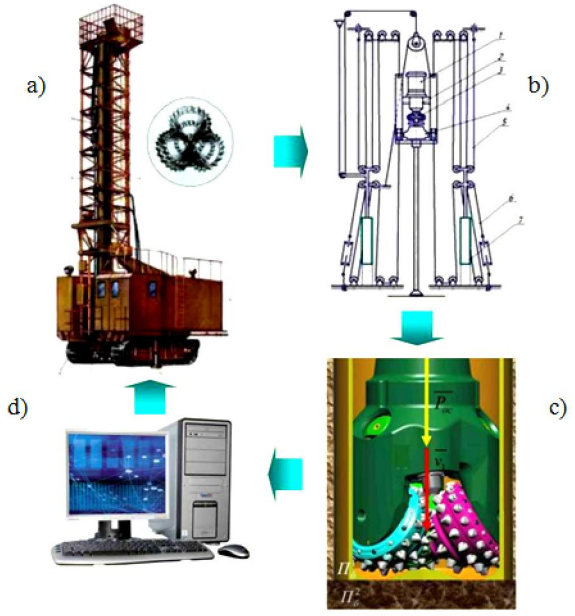

Fig. 2. Technological scheme of AIS with the short-duration nature of feedback:

a) a drilling rig; b) an adaptive rotational and feeding mechanism; c) drilling tools; d) a PC

In Figure 2 a) – a drilling rig, the main element of this technical system is given; b) – an auxiliary mechanism that can smooth unanticipated shock and vibration; c) – an element of the direct contact with the object of influence; d) – a complex of technical tools intended for automatic information processing.

Schematic diagram of the developed AIS operating is presented in Figure 3:

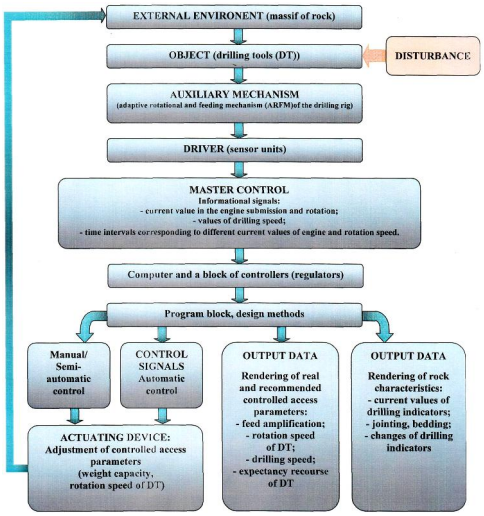

Fig. 3. Schematic diagram of the developed AIS operating with short-duration nature of feedback

This system is operated according to the following algorithm. The external environment (the rock massif: properties of the drilling breed and their unexpected changes) affects the process of the object operation (drilling tools) [21]. The given system requires the adaptive rotation-feeding mechanism of the drilling rig [22], a block of sensors, a PC and controllers. The object is also impacted by the disturbance independent on the control system: shock (reason for the operation mode changing of the drilling rig), noise (vibration, dust levels, temperature, instrument errors, failure in the control system). This mechanism allows us to smooth these unexpected disturbances.

A vibrodiagnostics system helps to predict the failure time of the main elements of the drilling rig is [18]; it allows us to analyze all the data and build time trends vibrations you can judge about changes of the technical condition of the equipment with.

To analyze the input information about the change of physical and mechanical characteristics of rock massif, sensors (drivers) send into the computer the information signals about changes of drilling and current speed in the stator of the adaptive mechanism

(master control). In computer these information signals are converted in control ones (the information about the actual characteristics of rock andcontrolled access) using the block of controllers (regulators, control units) intended to smooth short-duration deviations, the implementation of the control process and software block, which contains the developed calculation methods (control algorithm realization). Then the control signals are routed to the operation unit [23] implementing the decision making and the changes promoting in the relevant controlled access (automatic control). According to these methods projected resource of the drilling tool and unit costs of drilling, corresponding with the real values of controlled access and breed characteristics are determined. According to this information the optimal drilling speed and controlled access (output information) are determined. To improve the qualitative characteristics of the system we compare the real values with the optimal ones and they are automatically updated using the correcting units.

The rapid information transferring (a hundredth of a second) about the current operation modes of the control object from the object of control to the controllable part is implemented by the feedback. After adjusting actions an adaptive rotation-feeding mechanism works in the newly defined modes and it feeds and rotates the drilling tool with the necessary force and speed. The drilling tools pass through rock massif with the given speed until the following changes of the rock characteristics. The calculated values are displayed on the instrument panel to control an operator.

Conclusions

Summing it up we make the emphasis on the necessity of using the AIS with the short-duration nature of the feedback in the drilling rigs for the quick timely response of the system to properties changing of object of influence and the subsequent adjustments and parameters maintenance of operating the object of control in the optimal ratio.

Further the implementation of this AIS will allow us to reduce the operating costs for the drilling process in conditions of uncertainty and as consequence to increase the efficiency of technical systems operation.

Educts

1. The requirements for operability (timeliness) and the accuracy of information transferring, being the fundamental condition for improving the quality of control by the object and process are defined.

2. The problem concept of control by structural dynamics of complex technical objects is given.

3. The necessity of using the AIS with a short-duration nature of the feedback in drilling rigs and the advantages of the investigated AIS before its analogues are revealed.

4. The necessity of using the nonlinear feedback (a closed multi-circuit control system) and the combined systems to improve the control accuracy in the investigated AIS is specified.

5. The technological and the schematic diagram of the investigated AIS operation are developed.

6. The development of the AIS with a short-duration nature of the feedback involves the development of calculation methods, hardware, systems of data collection and processing, software, system modules, documentation development, system of testing.

Acknowledgements

Article is prepared within a grant of the President of the Russian Federation # MK-2531.2014.8 and support of the Ministry of science and education of the Russian Federation " High-produced calculations of complex algebraic systems and their applications".

The authors gratefully acknowledge the guidance and insights provided by Dr. A.V. Gilev of SFU, which greatly helped take their first step toward studying the issues related to boring machines.

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5/20/2014